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A Compact Dielectric Resonator Antenna for Ultra-Wideband Applications

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ABSTRACT

This paper produces A simple compact band-notched dielectric resonator antenna used for ultra-wideband (UWB) applications. A rectangular dielectric resonator with rectangular air gab in the middle is used to achieve the optimum bandwidth and optimum gain for the proposed design. To eliminate any possible interference and overlapping, a new technique is presented to make a notch-band for the frequencies that are already used in the UWB such as the WLAN band (5.2-5.6GHz) by etching slots in the feedline. By varying the length of the slots, we can obtain many notch bands at various frequencies. The proposed antenna has a −10 dB impedance bandwidth of 87% from 3.2 GHz to 10.6 GHz. The proposed antenna is simulated by two simulation programs which are basically different to confirm the results; CST Studio suite^{TM} 2020 simulator based on the Finite-Difference Time-Domain (FDTD) method and HFSS 15 from Ansoft based on the Finite-Element Method (FEM).

1. Introduction

In past years a dielectric resonator (DR) has been utilized as an energy storage device or a filter in microwave circuits. Later, in recent years, the researchers interest in using DR as an antenna [1]. Mostly researchers interest in using ultra-wideband (UWB) antenna ranging from 3.1 GHz to 10.6 GHz according to Federal Communication Commission (FCC) [2]. Ultra-wideband has different applications such as radar imaging and more recent applications in tracking, locating and target sensor data collection such as in door location, navigation, telemetry, remote Sensing, global positioning systems (GPS), the direct broadcast system (DBS) and mobile satellite communications [3,4]. Different designs can be used to get a UWB antenna such as using a patch, but a microstrip patch antenna is a less-efficient radiator and low profile compared to DRA (dielectric resonator antennas) [5-7]. For radiation, in a patch antenna, the radiation occurs at patch edges, but in DRA the radiation process includes all surfaces of DR [8]. DRA has more features and advantages that qualify it for using at this time such as wide bandwidth, light weight, better efficiency, low cost, ease of implementation, high gain, and high power capability due to the minimum conductor losses for DRA [9]. It comes in a variety of shapes to qualify its use in different applications, including conical, cylinder, triangle, rectangle, and spherical which makes flexibility in design [10]. This antenna at this wide bandwidth has more applications such as

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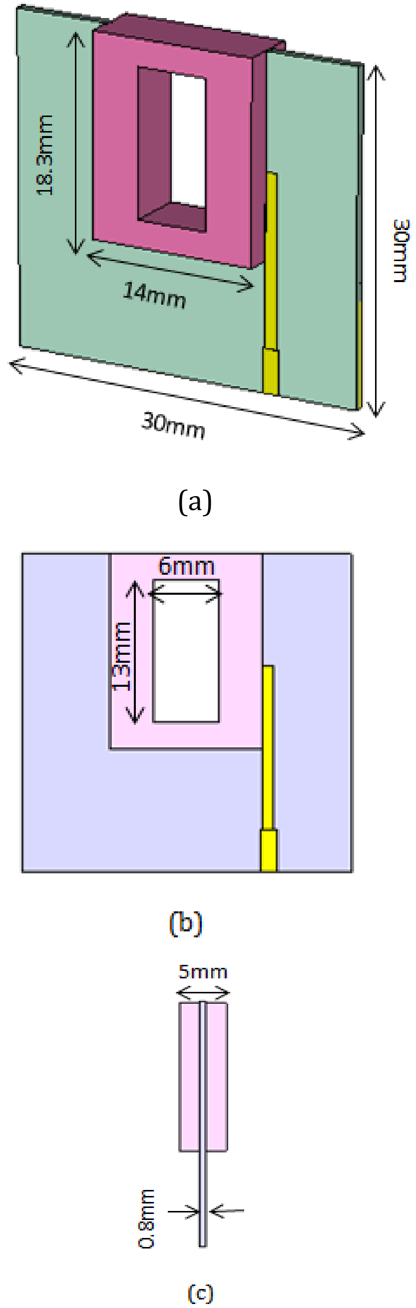
telemetry, navigation, biomedical system, mobile satellite communication, and use in communication applications including sensor networks, GPS (global positioning systems), and radar [11]. There are narrow frequency ranges existing in UWB that are used in communication systems and may cause overlapping. To reject these ranges from the operating bandwidth, using a technique of notch-band [12]. The band-notched antenna can be made using various methods such as etching slots in the feedline to filter out the unwanted bands [12,13], and this technique of etching slots in the feedline is used in the proposed antenna. In this paper, band-notched UWB DRA with high gain is proposed. The rectangular dielectric resonator has a rectangular air gap and its dimensions are optimized to get the optimum bandwidth and optimum gain. The proposed antenna is fed directly by the feedline. The impedance bandwidth of this antenna is about 87% for a frequency range from 3.2 GHz to 10.6 GHz. The resonance occurs at 6.4 GHz and 8.5 GHz. The maximum gain 5.5dBi.

2. Antenna Design and Configuration

Figure 1 shows the proposed antenna geometry. Rectangular DR is made of RogerRO3010 material with $\varepsilon_r = 10.2$ and has dimensions of (18.3 × 14 × 5) mm^3 with a rectangular air gap of dimensions (13×6×5) mm^2. DR is printed inside the substrate with FR-4 material. The substrate has dimensions of 30 mm × 30 mm × 0.8 mm, loss-tangent of 0.017and relative permittivity $\varepsilon_r = 4.4$. The ground plane is printed on another side of the substrate in the back with dimensions of (30 × 11) mm^2. The feeding mechanism is achieved by using a microstrip line that links the input signal to the antenna, with the length of $L_1 = 4$ mm, $L_2 = 13.5$ mm. The proposed antenna has dimensions of (0.32 λ_{min}, 0.32 λ_{min}, 0.053 λ_{min}) at the lowest frequency in the operating bandwidth. These dimensions are carried out by using CST Studio suite™ 2020 simulator and HFSS15 simulator.



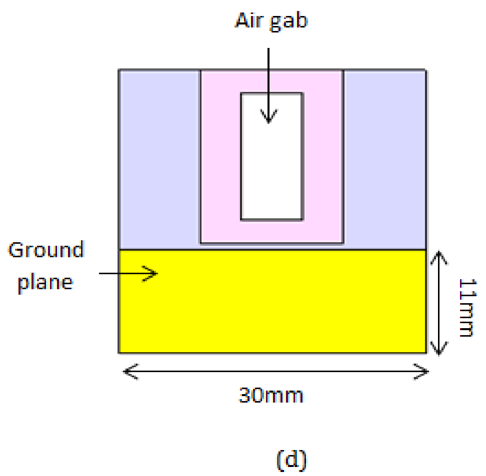


Fig. 1. Design and configuration of the rectangular DRA: (a) 3D view, (b) front view, (c) side view, (d) back view.

Figure 2 shows the curve of return-loss as a function of frequency by using HFSS and CST Studio simulators. Approximately the two curves are identical but there is a very small difference as the curve shown. The operating bandwidth of the proposed antenna is from 3.2 GHz to 10.6 GHz. The resonance occurs at frequencies of 6.5 GHz and 8.5 GHz. This antenna is designed, simulated and tested.

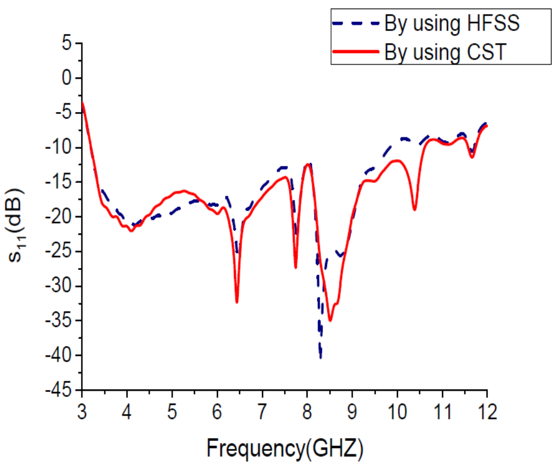


Fig. 2. Comparison between simulated return-loss plots by using HFSS simulator and CST simulator.

3. Notch-Band Implementation

After the design is introduced, there are some bands needed to filter out from the operating range. These bands are used in communications, one of the very important bands is WLAN (5.2-5.6GHz). WLAN can be rejected by making notch band in the operating bandwidth. This notch is achieved by cutting three rectangular slots from the feedline. LC circuit is provided by making these slots and worked as a stop-band filter. This band is known as notch-band. In this technique a part of the signal will be prevented from reaching the DR part, to avoid interference. Figure 3 shows the proposed antenna with slot design. This slot is designed to prevent a part of the signal from radiating at a notch frequency. Notch frequency can be changed until getting the desired notch frequency by changing the slot length.

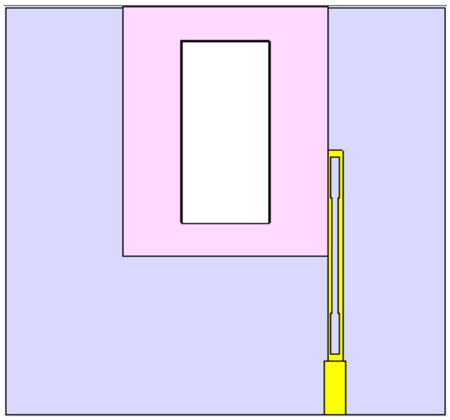


Fig. 3. Shows the slot that etched in the feedline and made a band-notch.

The main advantage of using this technique of cutting slots from the feedline is the flexibility in designing. Figure 4 shows the parametric study of varying slot lengths that change the location of notch-band frequency by using CST studio suite™ 2020 simulator. The design of this slot consists of three parts with different dimensions, two parts of them have dimensions of L = 3 mm, W = 0.6 mm and the third part has dimensions of L = 8.5 mm, W = 0.4 mm in the middle, to get a notch-band at WLAN band and prevent this band of the signal from radiation. Figure 5 shows the return-loss curves of the proposed antenna with a notch-band by using CST Studio suite™ 2020 simulator and HFSS 15 simulator. As shown in figure 5 the curve went up to the value of -4 dB at a notch frequency of 5.5 GHz. The two curves are nearly identical.

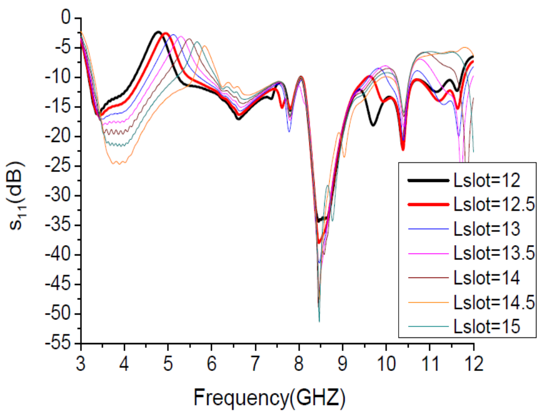


Fig. 4. Variation of return-loss behaviors with different slot length.

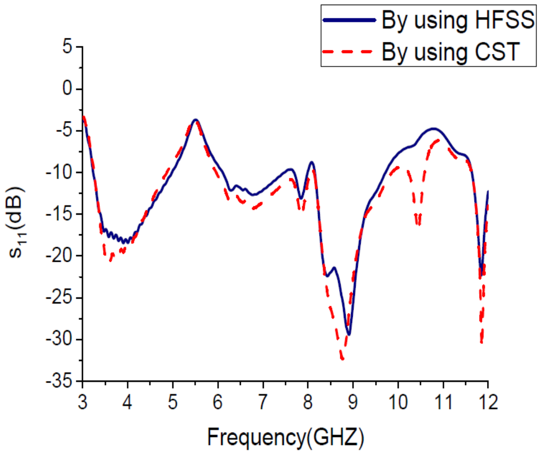


Fig. 5. The return-loss plots of the antenna with a notch.

Figure 6 shows the result of the gain of the proposed antenna with and without a notch by using CST studio suite^{TM} 2020 simulator. It is found that the maximum gain occurred at a frequency of 6.5 GHz with the value of 5.5 dBi and the range of the gain is nearly from 3 dBi to 5.5 dBi in the operating range. In the curve of the gain with a notch, the curve went down at a notch frequency of 5.5 GHz to the value of 0.5 dBi. Figure 7 shows the radiation efficiency as a function of frequency for two cases with and without a notch by using CST studio suite^{TM} 2020 simulator. As shown in this figure, the range of efficiency of the antenna without a notch is between 75% to 95%. The curve of efficiency with a notch went down at a notch frequency of 5.5 GHz.to a value of 47%.

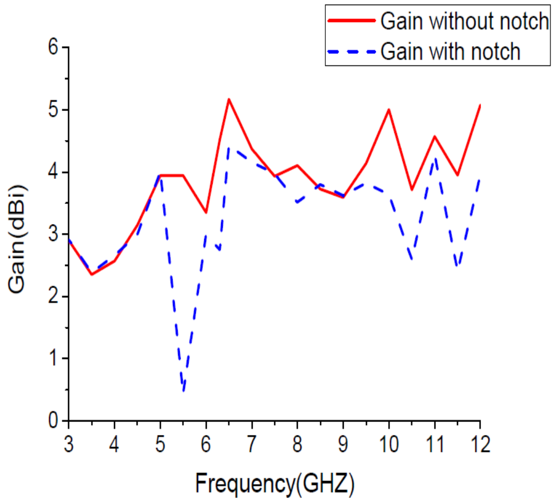


Fig. 6. Simulated gain for the proposed antenna.

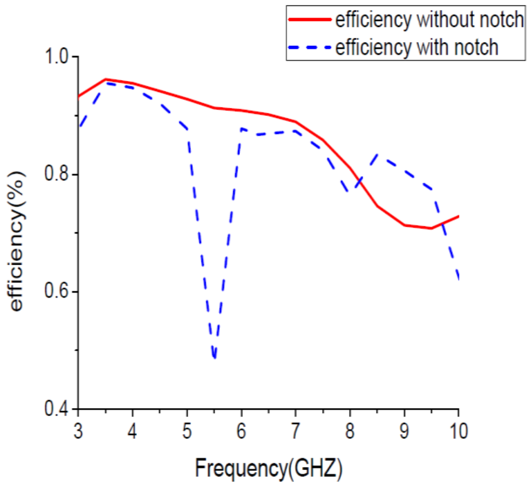
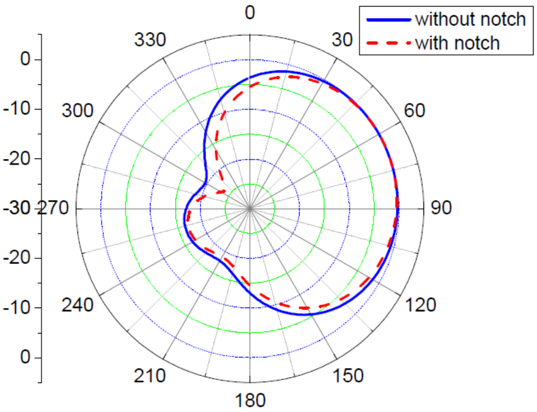
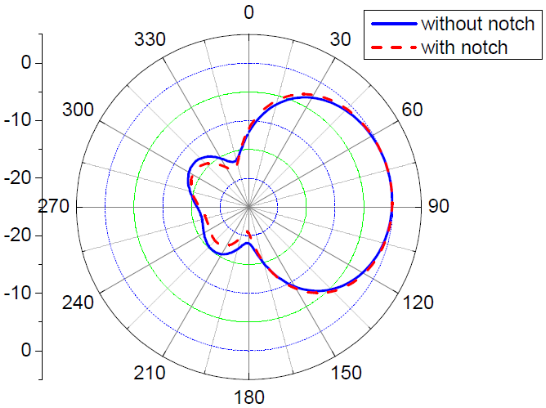


Fig. 7. Simulated efficiency for the proposed antenna.

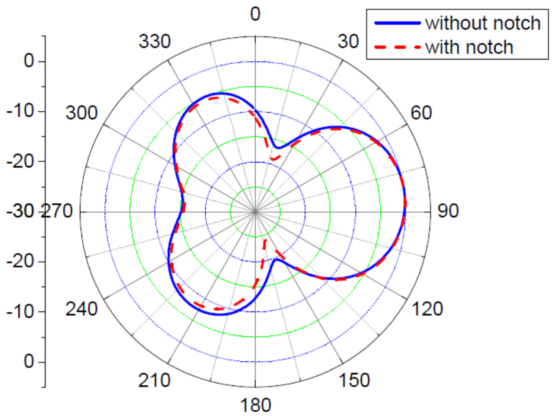
Figure 8 shows the normalized radiation patterns at the far-field by using CST studio suite^{TM} 2020 simulator for E-plane at phi=90 with and without notch for different frequencies including 5 GHz, 7 GHz, and 8.5 GHz. Figure 9 shows the normalized radiation patterns at the far-field by using CST studio suite^{TM} 2020 simulator for H-plane at phi=0 with and without notch for different frequencies including 5 GHz, 7 GHz, and 8.5 GHz.



(a)

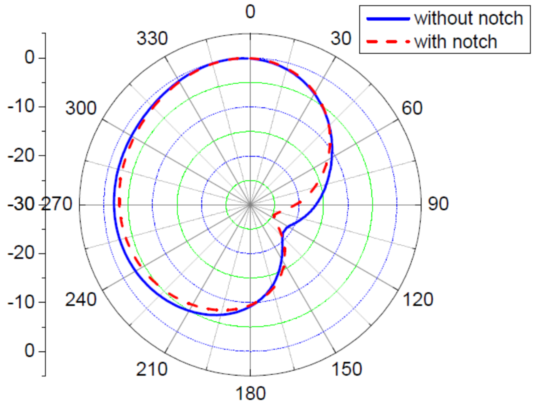


(b)

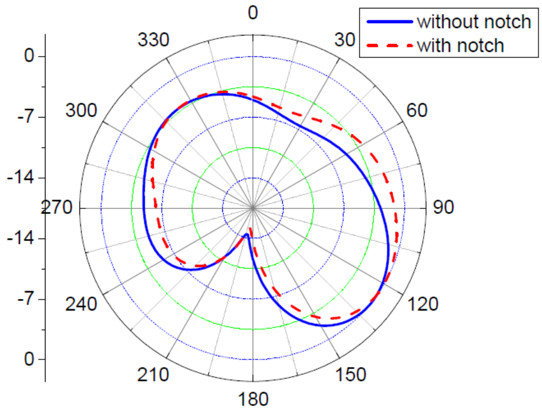


(c)

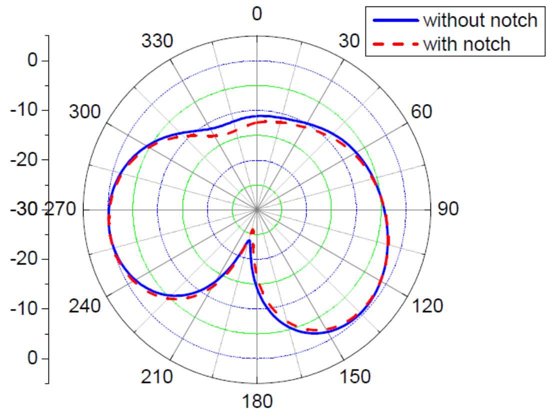
Fig. 8. E-plane of normalized radiation pattern at frequencies, (a) 5 GHz, (b) 7 GHz, (c) 8.5 GHz.



(a)



(b)



(c)

Fig. 9. H-plane of normalized radiation pattern at frequencies, (a) 5 GHz, (b) 7 GHz, (c) 8.5 GHz.

Table 1 compares the dimensions and results of our work with the early published papers.

Table 1. Antenna features and dimensions comparison between both our work and early published papers:

References	Total area(mm^3)	Operating bandwidth (GHz)	Eff. (%)	Gain (dBi)
[13]	27×25×6.8	3.844-8.146	NA	3-3.9
[14]	70×70×11	4-16	NA	2-4
[15]	NA	NA	85	3.5
[16]	60×60×10	2-12	87	Peak gain 6
Proposed work	30×30×5	3.2-10.6	Up to 95	3-5.5

4. Conclusions

The UWB DRA with a notch-band design has been demonstrated. The parameters of the proposed antenna are optimized by using two different simulation techniques: CST Studio suite^{TM} 2020 simulator and HFSS 15 from Ansoft to approve the results. The proposed antenna has a −10 dB impedance bandwidth of 87% from 3.2 GHz to 10.6 GHz. The gain had a range up to 5.5 dBi. Noise and interference are avoided in this design by making a notch-band at a notch frequency of 5.5 GHz and having a value of -4 dB. The efficiency had a range from 75% to 95% in the operating range. A high agreement is achieved in the dimensions and results. This design is suitable for using in many wireless communication applications and using in medical applications.

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